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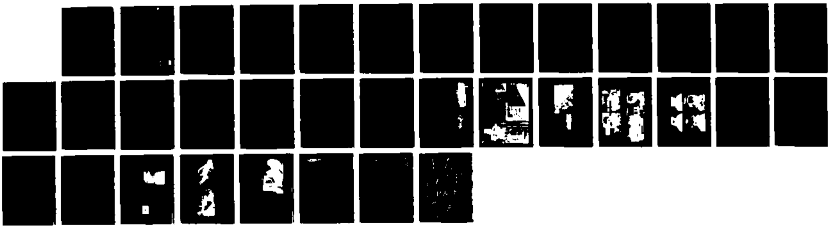

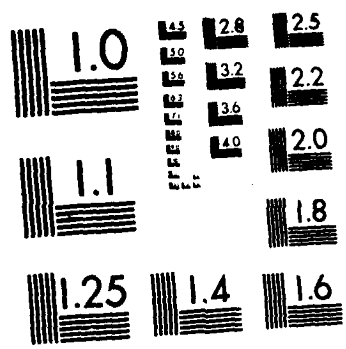

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The Naval Ocean Systems Center's Hawaii Laboratory is undertaking a program to develop airborne remotely operated devices (ARODs) and teleoperated land vehicles (TOVs) that will be delivered to the United States Marine Corps for field assessments of the applicability and effectiveness of such vehicles for reconnaissance and combat in tactical environments. An essential component of both remotely operated systems is a visual sensor suite and helmet-mounted display that allows an operator to view the remote scene in a familiar, natural fashion well enough to drive the TOV safely and reliably across unfamiliar terrain. In order to facilitate the development of this mobility sensor system, a field testing program has been established in which alternate mobility viewing system options are being objectively compared with regard to their impact on maneuverability.

This report describes the procedures and specific tasks used in making comparisons of maneuverability across the various viewing system options tested. The procedures were run with two groups of drivers, well-practiced civilian personnel who were tested with each of the viewing systems and enlisted Marine personnel who volunteered to be tested with a single mobility sensor system on a one-time basis. Specific results in terms of times through courses, steering, and braking accuracy are reported.

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ASSESSMENTS OF MANEUVERABILITY WITH THE TELEOPERATED VEHICLE (TOV)

by
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ABSTRACT

The Naval Ocean Systems Center's Hawaii Laboratory is undertaking a program to develop airborne remotely operated devices (ARODs) and teleoperated land vehicles (TOVs) that will be delivered to the United States Marine Corps for field assessments of the applicability and effectiveness of such vehicles for reconnaissance and combat in tactical environments. An essential component of both remotely operated systems is a visual sensor suite and helmet-mounted display that allows an operator to view the remote scene in a familiar, natural fashion well enough to drive the TOV safely and reliably across unfamiliar terrain. In order to facilitate the development of this mobility sensor system, a field testing program has been established in which alternate mobility viewing system options are being objectively compared with regard to their impact on maneuverability.

This report describes the procedures and specific tasks used in making comparisons of maneuverability across the various viewing system options tested. The procedures were run with two groups of drivers, well-practiced civilian personnel who were tested with each of the viewing systems and enlisted Marine personnel who volunteered to be tested with a single mobility sensor system on a one-time basis. Specific results in terms of times through courses, steering, and braking accuracy are reported.

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GROUND-AIR TELEROBOTIC SYSTEMS PROGRAM

Overview

The Ground-Air TEleRobotic Systems (GATERS) program was initiated in October 1985 in order to rapidly develop two distinctly different teleoperated vehicle systems which will be delivered to the U.S. Marine Corps for field assessments of their operational value in various tactical combat environments. The first remotely operated system, a small, flying vehicle has been designated the Airborne Remotely Operated Device (AROD). The second system, a remotely operated rough terrain vehicle has been designated the TeleOperated Vehicle (TOV). Though, on their surface, these vehicles look and function quite differently, they share several important features. Both are fiber optically tethered. Both use advanced, high-speed telemetry hardware to convey control and feedback signals back and forth across the fiber optic link. But, perhaps most importantly, both have developed out of a design approach that emphasizes the importance of providing the human operator with a sense of telepresence, an inside-looking-out experience of the remote system which is intended to impart a sense of being physically present in the vehicle throughout its operations.

AROD

The AROD is shown in both its planned and current forms in Figure 1. This vehicle is intended for out-of-direct-line-of-sight and nape-of-the-earth operation. AROD is compact, only 2 feet in diameter and 4 1/2 feet in overall height. It weighs approximately 80 lbs., including a 10 lb. payload. The unit is designed to remain airborne for up to one hour and is capable of up to a 30 knot translational speed. A stereoscopic pair of cameras is mounted to a pan-and-tilt mechanism on the side of AROD. This camera pair is aimed by head movements of the operator back at the control station. The control station itself is

small and lightweight enough to be back-packable. A joystick is used for vehicle control, and AROD will share its head-mounted stereoscopic display design with TOV.

TOV

TOV is essentially a remotely-operated High Mobility Multi-purpose Wheeled Vehicle (HMMWV). It is depicted in Figure 2. TOV is expected to provide a ground-mobile platform with the same maneuverability as a directly-operated HMMWV for both on-road and off-road operations. It will be used to conduct up to 24-hour continuous missions and must therefore be designed for both day and night operation. Overland range of the system will be up to 30 km. A mobile command center for control of up to 3 TOVs will be housed in an enclosure which can be lashed onto a single HMMWV. Several alternative mission modules for a variety of observation/surveillance missions as well as forward target designation and light *weapons engagement* will be attachable to the TOV.

TOV MANEUVERABILITY TEST METHODOLOGY

The main purpose of this report is to impart an understanding of the TOV fundamental mobility testing program which has been conducted in parallel with hardware development efforts undertaken at NOSC-Hawaii. The methods employed are intended to provide an objective means for making unbiased, quantitative comparisons among a wide range of mobility system design options.

Two Phases of Mobility Testing at NOSC

From a scientific viewpoint, the type of tactical reconnaissance driving that TOV should be capable of performing is extremely difficult to precisely characterize and study if one attempts to tackle the problem all at once. The

most reasonable approach is through progressive testing, i.e. starting with simple, standardized, replicable measures of driving performance and resolving issues of basic vehicular control before proceeding on to more operationally-relevant driving performance measures. Accordingly, the first phase of the TOV mobility testing program commenced with simple driving tasks carried out on clearly-marked courses, uncluttered surroundings, and unobstructed, level road surfaces. We refer to this phase of testing as fundamental mobility testing. In the remotely operated mode, the fundamental mobility test course places moderate to high demands on an operator's perceptual, orientational, and motor skills but only negligible demands on his interpretive, decision making, and problem solving skills - skills which vary widely among potential operators.

Once performance baselines have been established under fundamental mobility testing conditions, a second phase of testing , advanced mobility testing, will involve measurements conducted under more demanding driving conditions. Advanced mobility testing will require the operator to maneuver the vehicle through rough, uneven terrain with many natural obstacles such as trees, ravines, gullies, rocks, overhangs, and water hazards. Both fundamental and advanced phases of TOV mobility testing are illustrated in Figure 3.

Vehicle Control Conditions

For both phases of mobility testing, three different classes of vehicle control conditions will be tested. Direct Drive conditions are those in which the vehicle operator is physically present in the driver's seat of a HMMWV and has an immediate view of the test course. The Direct View condition, depicted in the upper left panel of Figure 4, is one in which the driver wears only a flight helmet with no face shield. There is no occlusion of his normal binocular field of view. This driving

condition provides a performance baseline which is equivalent to a 100% telepresence system against which all other viewing system options may be compared. Image resolution, contrast, and color sensitivity are not limited by a video system. They are limited only by the direct view eyesight of individual drivers. The condition also features "perfect" head motion coupling and the "normal" 1 to 1 spatial correspondence between perceived space and physical space. The Masked Direct View condition, a variant of the Direct View condition, is one in which the driver's view of the test site is partially occluded such that only the central 40° by 30° of his normal binocular field of view is visible. The Direct View and Masked Direct View conditions are shown in the two upper panels of Figure 5.

A second class of driving conditions is depicted in the upper right panel of Figure 4. It is referred to as the Direct Drive with Video View condition because the driver is physically present in the vehicle while driving it, but his view of the test course is provided solely by means of a video system. A pair of cameras is attached to the top of his helmet and these feed their signals into a pair of displays, each of which is seen by one of the operator's eyes. Opaque tape was used to mask off any direct view of the test course. Though resolution and contrast were greatly reduced, and color contrast was absent from the video images provided to the operator, the Direct Drive with Video View condition did provide him with a wealth of sensory information not readily available to a remote system operator. Body orientation relative to the vehicle and vehicle orientation with respect to its surroundings were immediately obvious to the operator. Camera slewing was well matched to the operator's head and upper body motions with only slight lags primarily caused by persistence in the CCD camera sensor used throughout all testing. And, except for the mismatch between visual and vestibular stimulation caused by the lack of 1 to 1 spatial correspondence in the display, vestibular and vibrational

information was generated by the physical movement of the vehicle and driver through the courses. To date, the two helmet-mounted display systems shown in the two lower panels of Figure 5 have been tested under Direct Drive with Video View driving conditions. The lower left panel in Figure 5 shows a helmet mounted display which was developed at NOSC-Hawaii in 1981 for use with the Advanced Technology Teleoperated Vehicle (ATTV) - an earlier prototype all-terrain vehicle. The display system weighs approximately 7 lbs. and provides its wearer a 22° by 16.5° stereoscopic, monochromatic field of view. The display shown in the lower right panel of Figure 5 is a modified Honeywell Integrated Helmet And Display Sighting System (IHADSS). The system weighs less that 5 lbs. and provides its wearer a 40° by 30° stereoscopic, monochromatic field of view.

The Remote View driving condition, shown in the lower panels of Figure 4 has not yet been tested in either phase of the mobility testing program. When TOV is ready for Remote View driving, the operator at the control station will be provided with a stereoscopic display of the test courses, accurate head motion coupling, and stereophonic sound.

Subject Groups Tested

Data reported here were measures of fundamental maneuverability taken from two groups of drivers. The first group of drivers, hereafter referred to as the experienced group, consisted of four civilian personnel who were practiced both at driving the HMMWV and at negotiating the specific courses used in Phase One of testing. For Direct View and Direct Drive with Video View with the IHADSS and ATTV displays, these subjects were run through each of the courses ten times prior to the commencement of actual data collection. A graphical analysis of measures taken during these course familiarization sessions showed that all subjects had reached

asymptotic levels of performance on all measures taken by the conclusion of the practice sessions. Each of the experienced drivers was run under all viewing conditions tested and described in detail below.

The second group of drivers, hereafter referred to as the inexperienced group, consisted of 5 detachments of 4 Marine enlisted men each. These men volunteered to serve as test drivers on a one-time basis. All subjects tested had normal or corrected-to-normal visual acuity and all had previous familiarity with the HMMWV. At the beginning of a test session they were driven around the entire set of courses by the data collector and instructed as to the specific procedures for each course. Then, immediately prior to testing, they were allowed one practice drive through each course under Direct View conditions. Inexperienced drivers were used in order to gain an appreciation for the effects of learning and experience on driving performance under the various viewing conditions tested.

Fundamental Maneuverability Battery

The TOV fundamental mobility test program employs a battery of simple driving tests in an attempt to measure low-speed maneuverability under more or less ideal driving conditions. Six driving courses which comprise the fundamental mobility test battery were selected on the basis of a factor analysis of 58 measures of low-speed maneuverability [1] conducted at the University of Michigan's Highway Safety Research Institute (HSRI). The battery provides a cost-effective, reliable, reasonably sensitive and comprehensive metric against which TOV system design options can be assessed and improved in a systematic fashion. The testing courses, described in detail below, were surveyed and marked off on an unused runway area of the Kaneohe Marine Corps Air Station within 1/2 mile of NOSC's Teleoperator Development Center.

Description of Driving Courses and Measurement Procedures

Though the general layout of courses used in this paper was described in the HSRI's report, some modifications of courses and procedures were required for testing with TOV and so the courses are once again described in detail here. Bright orange, 30-inch tall traffic cones were employed to mark off all courses. In some instances (see Figures 6 and 8), 6-foot tall sticks were inserted into the cones. Order of testing for courses was identical for all subjects on all days of testing and followed the order in which they are described below. For all measures taken, verbal instructions were given which emphasized the importance of accurate error-free driving and de-emphasized the importance of speed through the courses.

Course 1. Right Angle Turn- IN

The first course run during each test session is depicted in the left panel of Figure 6. A pattern of traffic cones defined an 11-foot wide right angle parking space with a 19-foot wide access lane perpendicular to it. The driver's task was to start at one end of the access lane and pull as far into the parking space as possible without touching any of the cones defining the course or touching the stick at the end of the alley with the bumper of the vehicle. The original HSRI scoring regimen called for measuring the distance from bumper to stick, but so many overruns of the parking space endpoint occurred during testing under Direct Drive with Video View conditions that it was decided to score this course in terms of proportion of times operators drove through the course without overrunning the endpoint. The Right Angle Turn-IN course was driven a total of 6 times per session, 3 times each from right and left start positions.

Course 2. Right Angle Turn- OUT

As the right panel in Figure 6 illustrates, starting from the position in which the vehicle rested following the previous Right Angle Turn-IN Trial, the vehicle was backed into the access lane. It was driven out of that lane in the same direction from which it had been driven into the parking space from the previous Right Angle Turn-IN trial. Drivers were scored for the number of cones touched during the maneuver. As with the Right Angle Turn-IN procedure, 6 measures were taken, 3 from each start position.

Course 3. Figure-8

The next course run was one in which the operator drove the vehicle through a "figure-8" pattern. The course is depicted in Figure 7. Spacing between the cone gates had to be widened from the original HSRI separation in order to accommodate the relatively wide turn radius of the HMMWV. A single run through the course consisted of three consecutive circuits through the figure-8 pattern. Drivers were scored for the number of cones which they touched or toppled while driving the course.

Course 4. Small Radius Circle

The Small Radius Circle course is depicted in the left panel of Figure 9. The START position was 100 feet from the first gate of the course. Operators drove the course twice from each of the two START positions shown in the figure. They were scored for the number of coned touched or toppled.

Course 5. Small Radius Circle with Stop

The Small Radius Circle with Stop course is depicted in the right panel of Figure 9. A stop cone with a stick inserted in it was positioned in the middle of the alley at the apex of the horseshoe-shaped course. Operators were instructed to drive the vehicle as close as possible to the stick without touching it. Again, as with the Right Angle Turn-IN course, so many overruns occurred in the Direct Drive with Video View condition that the course was scored in terms of proportion of overruns of the stop stick rather than by the distance between the bumper and the stick. The course was run twice from the two START positions shown in the figure.

Course 6 Gymkhana

The gymkhana course was a large, oval-shaped slalom course depicted in Figure 10. Three runs through the course were measured during each test session. Driving was scored in terms of the number of cones touched or toppled.

TEST RESULTS TO DATE

Description of Statistical Analyses Employed

Measures from each of the courses described above were compiled and subjected to separate analyses of variance with comparisons across 5 viewing conditions (Direct View, Direct View 40° by 30°, IHADSS-Stereoscopic, IHADSS-Monoscopic, and ATTV) being the main factor of interest in each analysis. An alpha level of .05 for statistical significance was set prior to analysis. Separate analyses were run for the experienced and inexperienced subject groups. Findings are presented in somewhat condensed tabular form to summarize results from all courses run across five design topic areas. A more detailed account of these results will be made available in a forthcoming NOSC technical publication by the same author [2].

Results by Topic Area

Direct View vs. Direct Drive with Video View

Were the courses chosen for the fundamental mobility test battery so easy to drive through that no differences could be found between direct driving performance and performance under Direct Drive with Video View conditions? Not surprisingly, all statistically significant differences that were found favored the direct view condition. The pattern of results that emerged from mean comparisons subsequent to the analyses of variance is presented in Table 1. In the Table, a "+" symbolizes a significant advantage for the Direct View condition, and a "=" symbolizes no significant difference between performance on the Direct View and Direct Drive with Video View conditions.

TABLE 1.
Direct View vs. Direct Drive with Video View
Mean Comparisons

	Subject Group	
Measures of Driving Accuracy	Inexperienced	Experienced
Right Angle Turn-In (Overruns)	+	+
Small Radius Turn (Overruns)	+	+
Figure-8 (Cones Hit)	+	=
Gymkhana (Cones Hit)	+	+
Timed Measures		
Right Angle Turn-IN & OUT	=	+
Small Radius Circle	=	+

In summary, statistically significant differences were found for each of the 6 measures taken in the fundamental mobility test battery, and all differences found showed the Direct View condition to be superior to the Direct Drive with Video View conditions tested. Differences were notably inconsistent between the 2 subject groups tested, with inexperienced operators producing more errors on accuracy measures and experienced operators driving the time-scored courses more slowly under Direct Drive with Video View conditions.

Direct View vs. Masked Direct View

With the visual information provided under direct view conditions, were any differences found between the unoccluded direct view condition and the 40° by 30° masked direct viewing condition? None were found on any of the courses tested for either subject group. The findings suggest that if sufficient image resolution, contrast and color head motion coupling, and accurate feedback of vehicle dynamics are provided to an operator a 40° by 30° FOV is sufficiently large enough for low-speed maneuverability under the conditions tested.

Stereoscopic vs. Monoscopic Video View

Measures were taken with the same IHADSS helmet-mounted display under two viewing conditions. In the IHADSS-Stereoscopic condition the left and right cameras mounted atop the helmet fed their video signals to the corresponding left and right eye displays. For the IHADSS-Monoscopic condition, the signal from the right camera was split and fed to the both left-eye and right-eye displays. When these two viewing conditions were compared in the analyses, no significant differences were found on any of the courses

tested for either subject group. This suggests that under the driving conditions tested, stereoscopic imagery provided no significant advantages over a simpler monoscopic imagery. In attempting to generalize this finding to more rigorous driving conditions, however, one must remember that past research has shown that the advantages stereoscopic imagery provides are most pronounced in unfamiliar, visually cluttered and in visually degraded scenes. Stereoscopic imagery is also useful in judging the relative distances and orientations of objects and terrain surface features - all of which might prove invaluable to an operator in "reading " terrain before attempting to traverse it. For these reasons, a much more relevant (meaningful) comparison of performance with stereoscopic and monoscopic imagery remains to be made during the advanced mobility testing phase of the program.

Spatial Correspondence

Neither of the helmet-mounted displays that have been tested to date provide a perfect match in spatial correspondence between the directly-viewed scene and a video view of that same scene. Using the same pair of video cameras and lenses, both systems minify the operator's view of the remote scene. That is, they compress the field of view taken by the cameras into a smaller field of view at the display. They perform this minification to varying degrees. The IHADSS display provides a minification at .77 and the ATTV at .42. Thus, the operator's view is more minified when wearing ATTV display than when wearing the IHADSS (in either monoscopic or stereoscopic display mode). In general, the more minified a display, the further objects appear to be located from the operator's viewpoint and the more rapidly they appear to loom as they are approached. While the comparison is confounded by several important factors such as display weight and

resolution, it is worth noting that comparisons between the ATTV and IHADSS display conditions reveal several interesting differences in driving accuracy measures that may be largely attributable to the spatial correspondence which they provide operators. These results are summarized in Table 2. In the Table, a "+" symbolizes a significant advantage was found for the stereoscopic display, a "-" symbolizes that a significant advantage was found for the monoscopic display, and a "=" symbolizes that no significant difference was found.

TABLE 2.
Effects of Spatial Correspondence
Mean Comparisons

Measures of Driving Accuracy	Subject Group: Inexperienced	Subject Group: Experienced
Right Angle Turn-In (Overruns	=	+
Small Radius Turn (Overruns)	+	+
Figure-8 (Cones Hit)	=	=
Gymkhana (Cones Hit)	-	=

No significant differences for either of the timed measures were found between IHADSS and ATTV displays for either subject group. Three of the four significant differences which were found involved driver's overrunning course endpoints - precisely the type of error one would expect from a display that caused operators to underestimate the distances to objects in the remotely-viewed scene.

While these results are not conclusive, they do suggest that better matching to direct view spatial correspondence may provide improved performance. They do not preclude the possibility suggested by a substantial body of data [e.g., 3] that

a slight magnification of the scene through the video system might provide even greater improvements in driving performance.

Experienced vs. Inexperienced Drivers

The effect of operator experience on driving the HMMWV can be summarized quite simply. The experienced group made fewer driving errors on all four measures of driving accuracy. The inexperienced group was faster on both timed measures of driving performance. This pattern of results suggests that with several hours of experience driving the TOV drivers became more cautious and lowered their driving speed to better correspond to their degraded view of the courses.

FUTURE EFFORTS

Testing efforts are currently focussed on completing the fundamental mobility testing phase when the fully remotely operated TOV system becomes available. In the meanwhile, efforts are underway to establish Direct View baseline performance measures on the advanced mobility test courses.

Area of Interest (AOI) Insert Display

New display systems are also being developed which will be assessed by both the fundamental and advanced mobility test program designs. Currently, these new displays are being developed under a contract with EG&G - Energy Measurements Inc. at Kirtland Air Force Base in New Mexico. In order to overcome the bandwidth limitations imposed by available video hardware and the existing telemetry system for TOV, and to more closely match display resolution to the spatial acuity function of the human eye while providing a useful stereoscopic image, the AOI insert approach will be used. The

left panel of Figure 10 illustrates the basic concept to be employed. One of the operator's eyes will be provided with a relatively wide (i.e., 60° by 45°) field of view. For the other eye, the same number of picture elements are presented in the central 20° by 15° area of the visual field. These picture elements map the same area in the remote physical scene as the corresponding area in the other eye, but with considerably higher resolution. This general approach has been used previously with some success [4], so it was decided to build a working prototype for use in the mobility testing program. This prototype is depicted in the right panel of Figure 10. The system was successfully demonstrated in the laboratory with 10-12 individuals. All individuals tested reported that the system produced the impression of a fused, wide field of view with a relatively high resolution, stereoscopic central field of view. However, the AOI insert prototype depicted in Figure 10 was too heavy and unwieldy for field mobility data collection.

More recent attempts have concentrated on reducing the size and weight of this type of display and on providing a comfortable but tighter fit of the HMD to the operator's head. Two new prototype HMD systems are being built for mobility testing during the late Summer and Fall of this year. The first of these prototype display systems is shown from front and side views in Figure 11. The display employs fiber optic bundles to convey images from a pair of high resolution CRTs mounted at the rear of the operator's head to dioptrically adjustable eyepieces immediately in front of the operator's eyes. The system will be reconfigurable for testing purposes to provide 20°/60°, 60°/20°, and 60°/60° fields of view to the wearer.

Retroreflective Screen Display

The second prototype HMD under development will employ a lightweight retroreflective screen to convey wide

field-of-view images into the operator's eyes. This stereoscopic display concept, originated by Steve Hines of HinesLab in Glendale, CA, is depicted in Figure 12 along with a photograph of one of the prototype display designs being prepared for testing. Due to their reflective corner cube configuration at microscopic scale, retroreflective screens reflect light back out along very nearly the same direction from which it strikes the screen. By employing a simple beamsplitter it is possible to position the operator's eyes at points optically coincident with a pair of projection lenses.If an equivalent lens is used for taking the images with a video camera and projecting them back in the display, excellent geometric correspondence can be achieved even with very wide angle lenses. Though approximately half the brightness available from the CRTs is "lost" to the beamsplitter, most of the remaining light is reflected back from the retroreflective screen directly into the operator's eye. Thus, when properly configured, the retroreflective approach is capable of providing a light-weight, relatively inexpensive, wide field-of-view helmet-mounted display that also has the potential for conveying very high resolution video images at relatively high brightness levels.

However, as with any other new display concepts, whether the new displays under development enable a driver of a remotely-operated all-terrain vehicle to operate his system with greater precision and efficiency remains a question to be answered by a systematic field testing program.

ACKNOWLEDGMENTS

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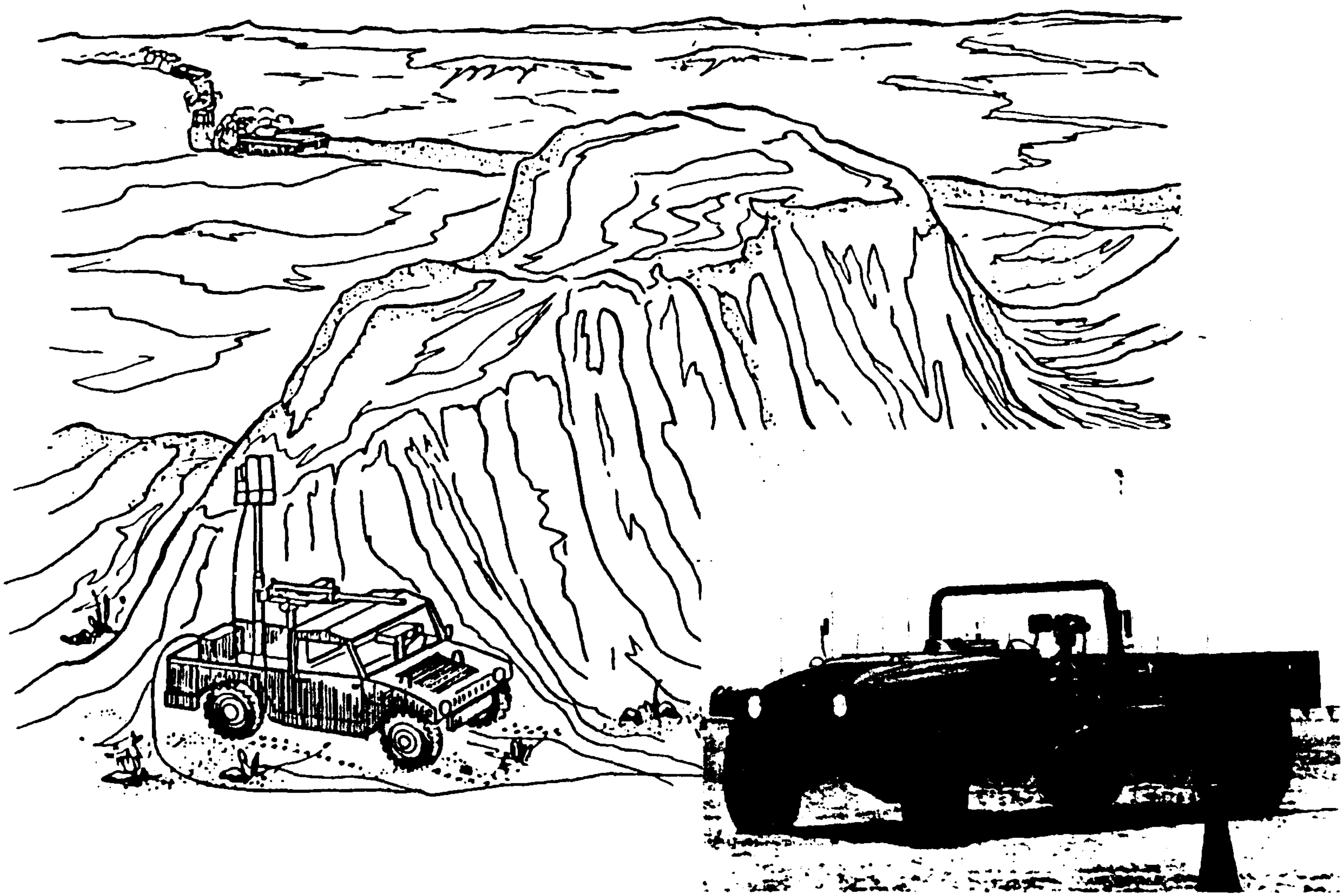
Figure 1. TOV — Teleoperated Vehicle



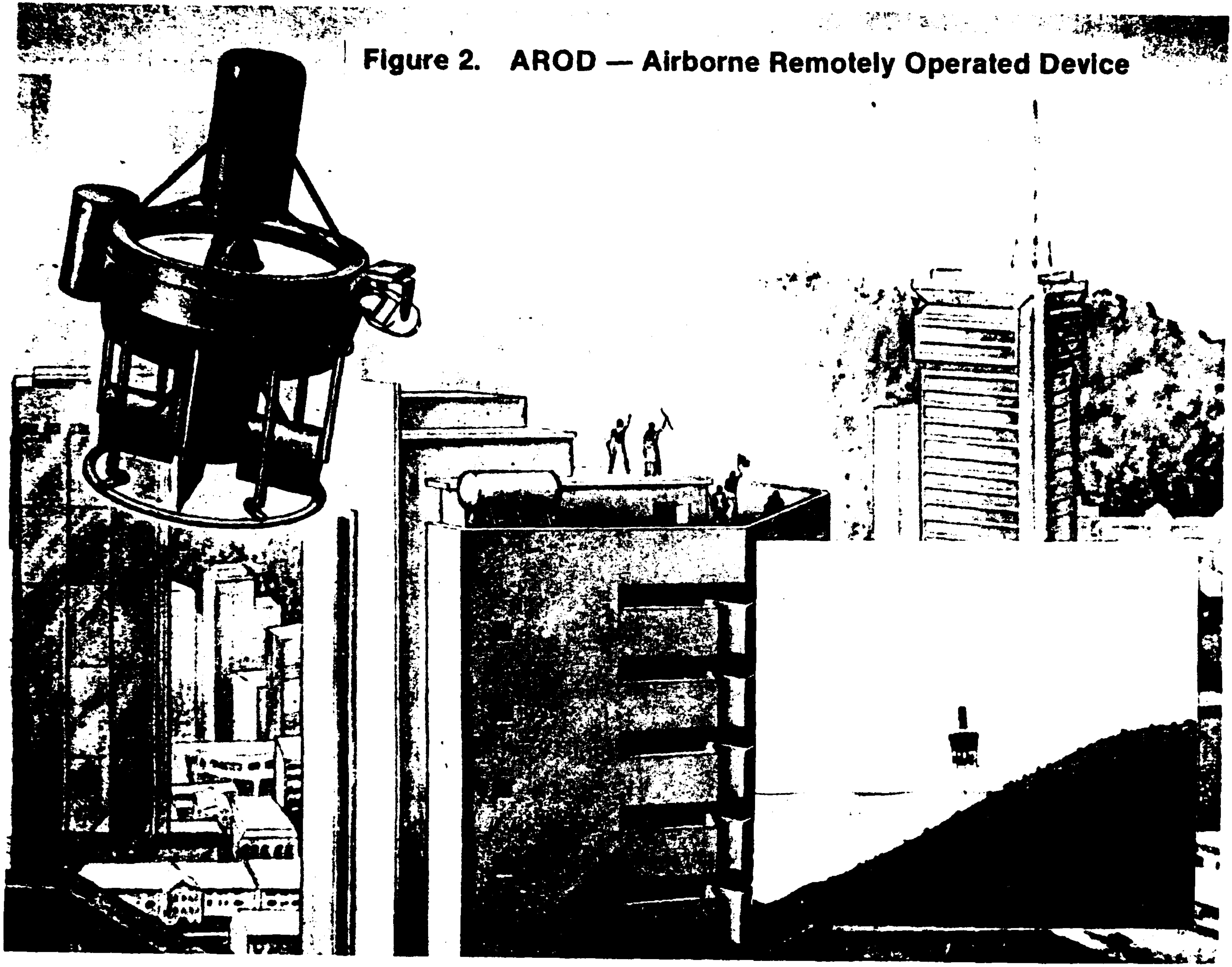


Figure 2. AROD — Airborne Remotely Operated Device

Figure 3. Two Phases of TOV Mobility Testing

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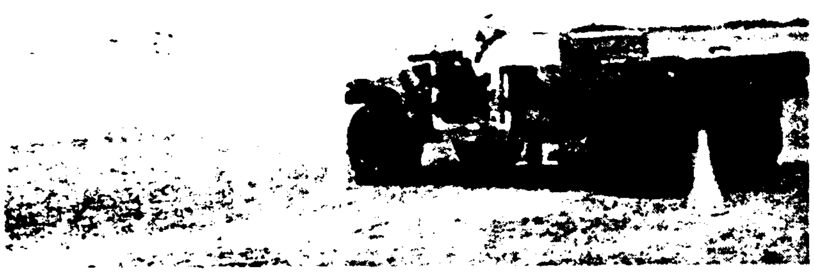
	
• Paved roadtop • Level • Clearly marked • Repeatable	• Unpaved, rough road • Sloping surfaces • Operationally relevant maneuvering

Figure 4. TOV Driving Conditions

DIRECT DRIVE

- Provides full "telepresence" baseline
  - — Eye limited resolution
  - — 1:1 spatial correspondence

DIRECT DRIVE WITH VIDEO VIEW

- Vehicle and body orientation obvious
- Head motion slewed cameras — minimal lags
- Match of visual/vestibular sensory inputs

REMOTE DRIVE

- Stereo imagery
- Stereophonic sound
- Head motion coupled helmet-mounted display

Figure 5. Viewing Alternatives Tested

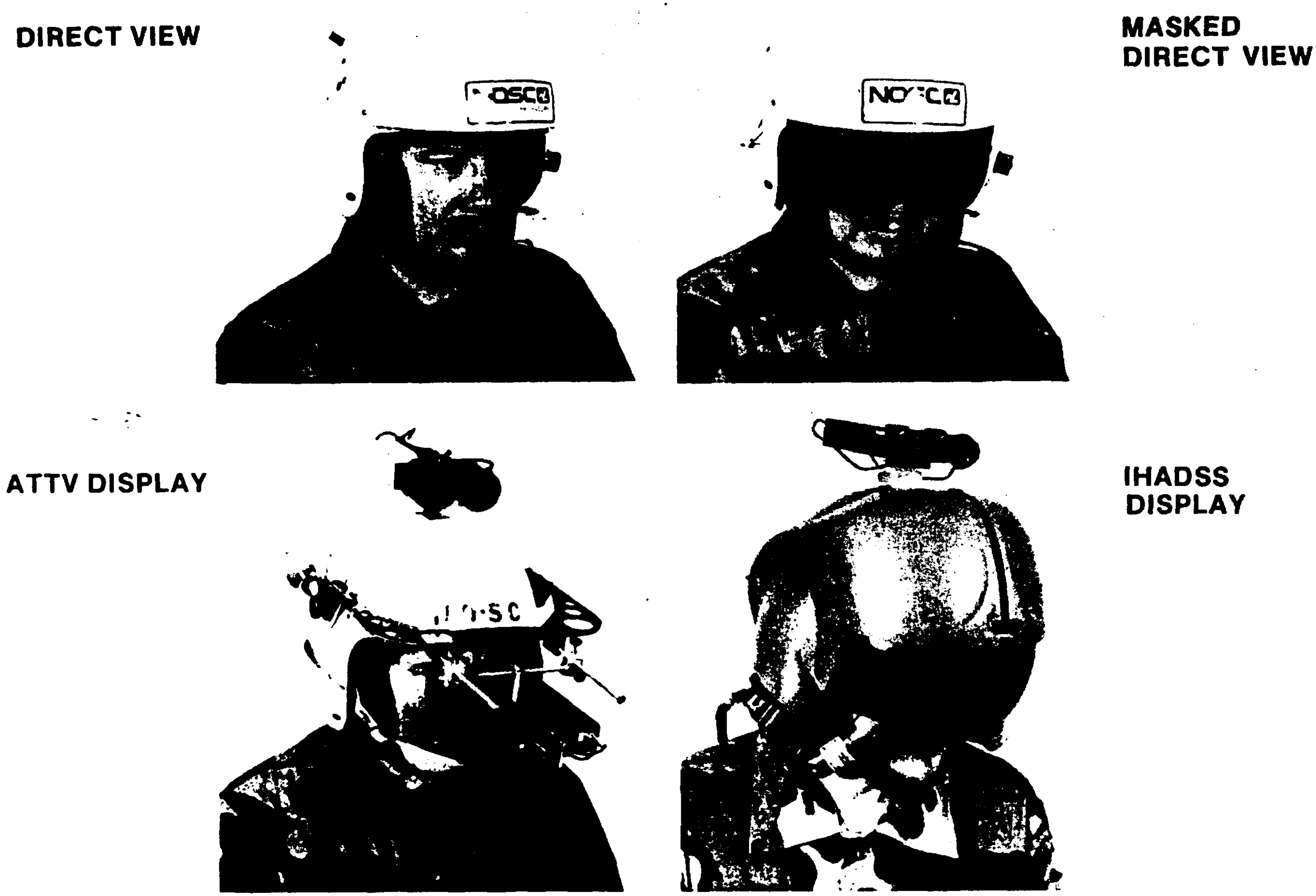
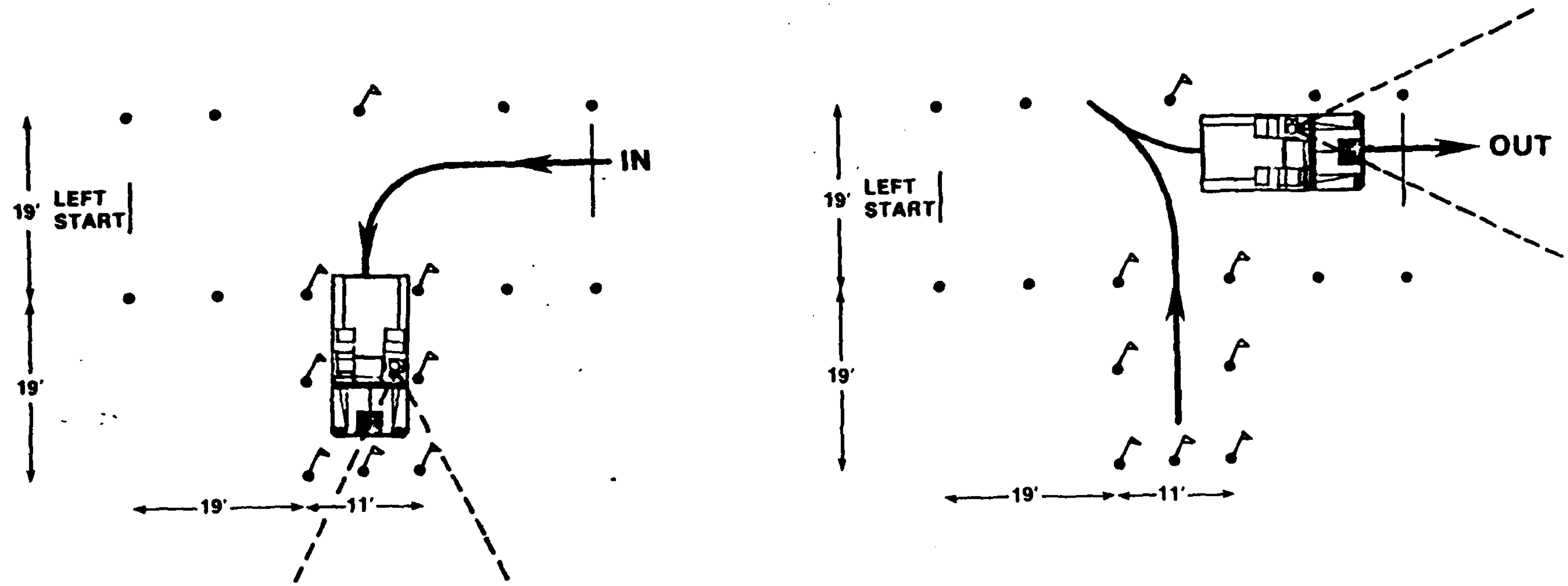


Figure 6. TOV Fundamental Mobility Testing

Courses 1 & 2. Right Angle Park



Right angle park-in measured very low-speed forward turning in a confined space

Right angle park-out measured reverse turning

Figure 7. TOV Fundamental Mobility Testing

Course 3. Figure-8 Course

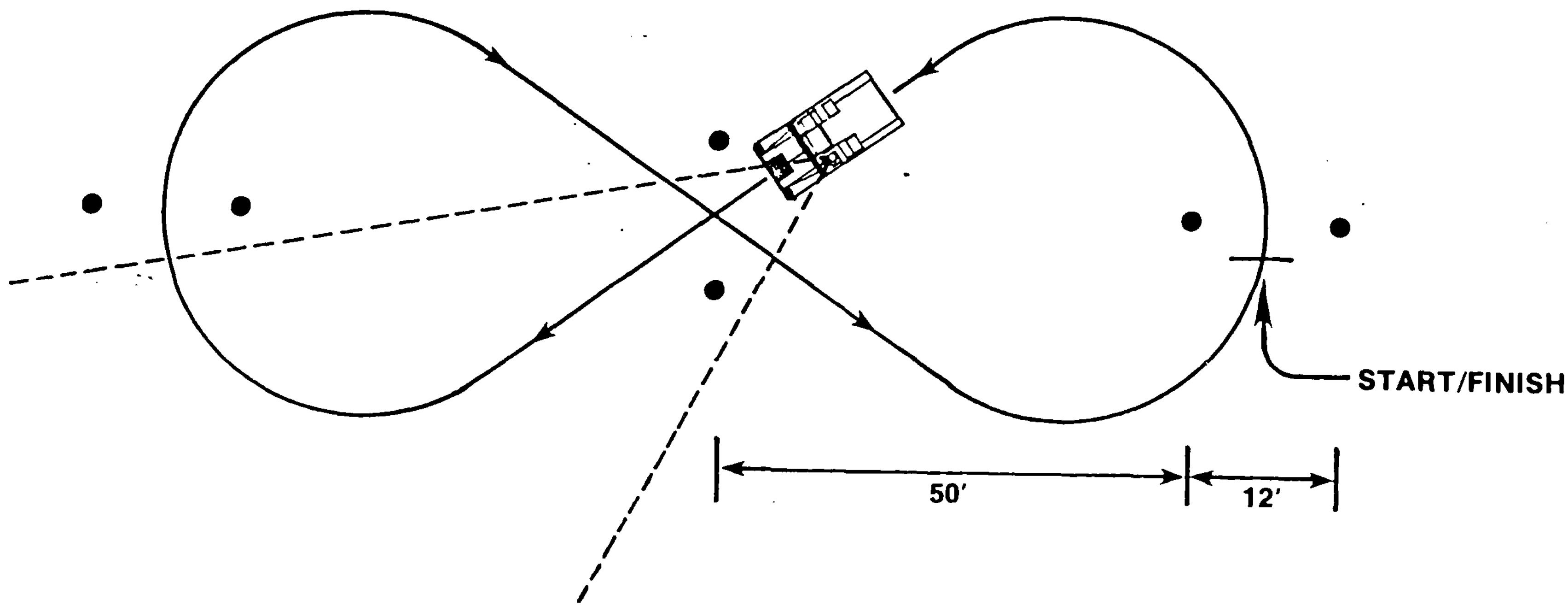


Figure 8 measures precision steering under time pressure when the pathway is defined by only a few points of reference

Figure 8. TOV Fundamental Mobility Testing

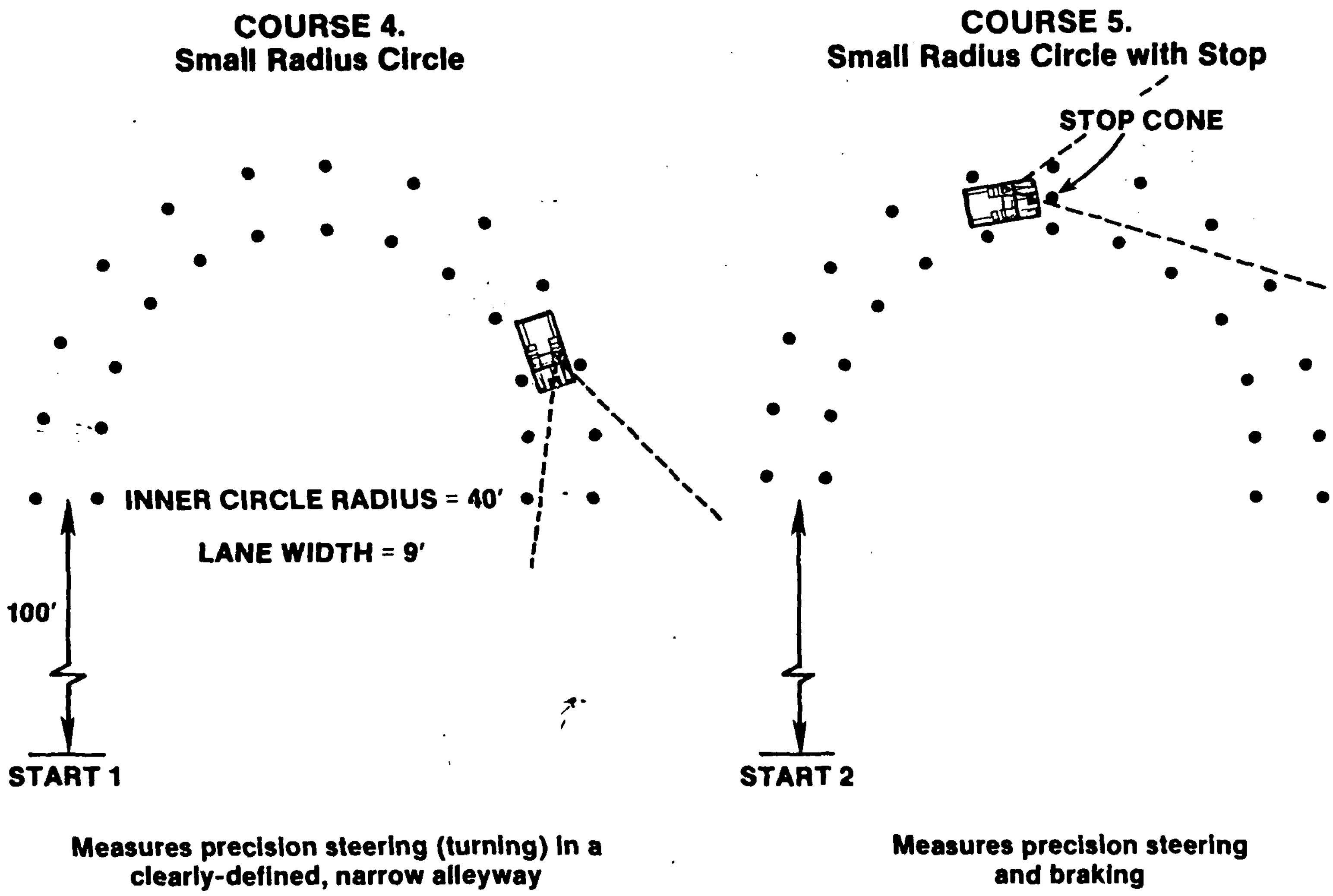
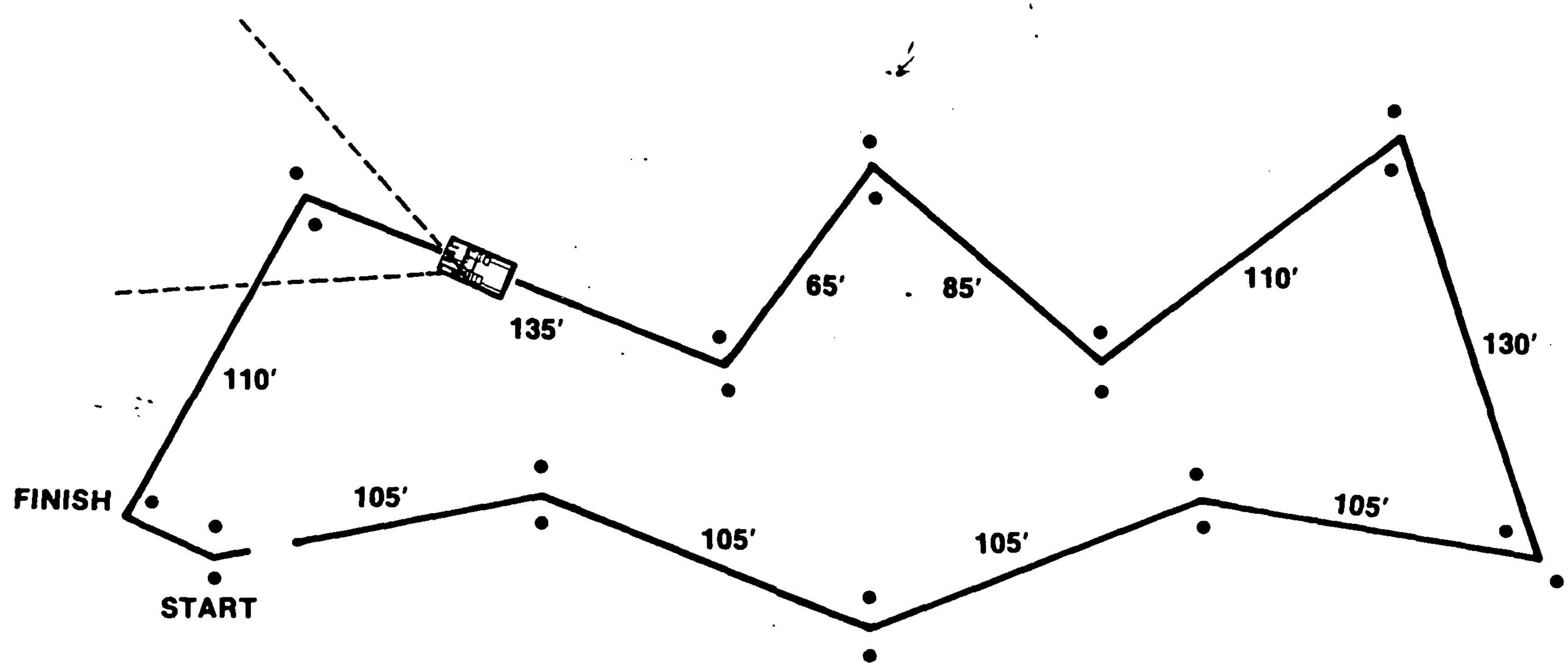


Figure 9. TOV Fundamental Mobility Testing

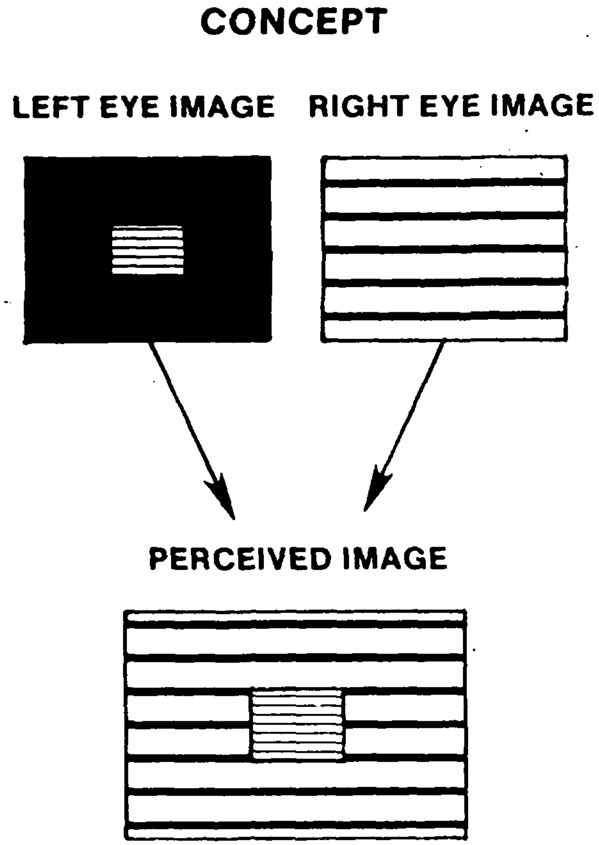
Test 6. Gymkhana



GATE WIDTHS = 9 FT

Gymkhana measures precision and speed control (up to 40 mph) under time pressure

Figure 10. Area of Interest (AOI) Insert Display



INITIAL PROOF OF CONCEPT DESIGN

Figure 11. Fiber Optic AOI Insert Display

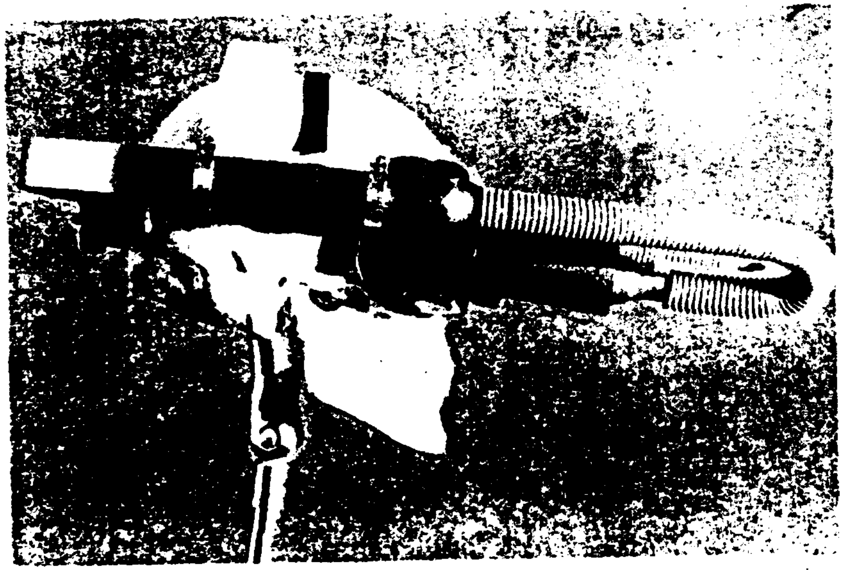
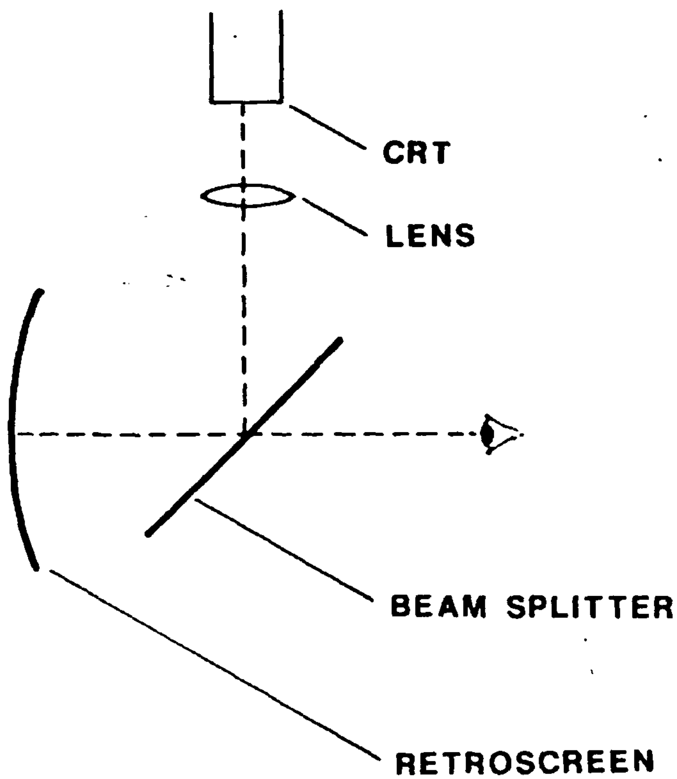
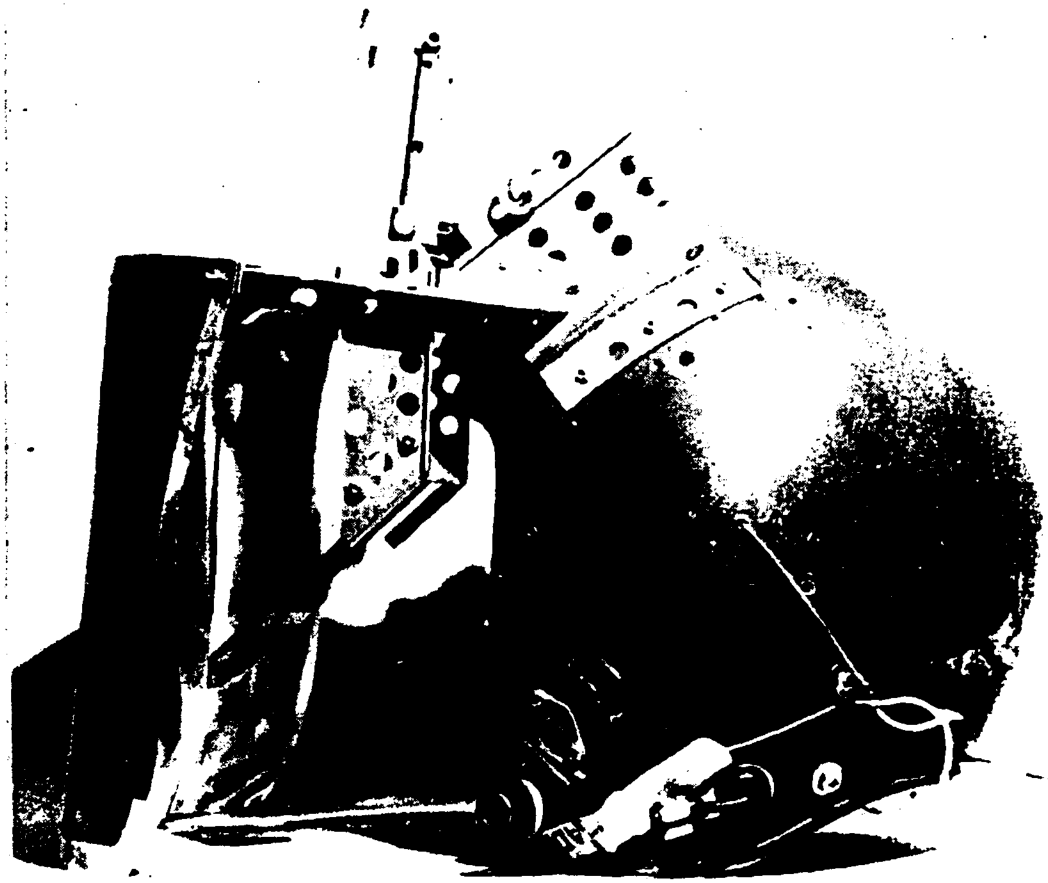


Figure 12. Retroreflective Display

SYSTEM CONCEPT



HELMET-MOUNTED DISPLAY PROTOTYPE



NOSC
HAWAII LABORATORY

MEMORANDUM

Date: 12-23-87

From: HUGH SPAIN, Code 533

To: JUNI JODZIO, Code 9611

Subj: AUVS PAPER

ATTACHED is A copy of the paper you requested on 8 Dec. Sorry for the delay. I've been away from my office on travel. The work was done in support of the Ground-Air TELErobotics Systems (GATERS) Project. The NOSC project number is C1699.

If there are any questions please call me at (808) 257-1626.

H.S.

ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS

1133 FIFTEENTH STREET, N.W., WASHINGTON, D.C. 20005 TELEPHONE (202) 429-9440

UVS ASSOCIATION

ESTABLISHED 1972

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ASSESSMENTS OF MANEUVERABILITY WITH THE TELEOPERATED VEHICLE (TOV)

EDWARD H. SPAIN

NAVAL OCEAN SYSTEMS CENTER

A PAPER PREPARED FOR PRESENTATION AT THE

FOURTEENTH ANNUAL SYMPOSIUM OF THE

ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS

THE SHERATON WASHINGTON HOTEL

WASHINGTON, D.C.

JULY 19-21, 1987

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